Recovery of the Cave Crayfish (Decapoda: Cambridae) Population in Peacock Springs, Florida?

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ABSTRACT—In 1991, a cave fauna kill was observed within the fully-flooded cave system at Peacock Springs, Suwannee County, Florida. Organisms affected by the kill included the pallid cave crayfish (*Procambarus pallidus*), the yellow bullhead (*Ameiurus natalis*), the American eel (*Anguilla rostrata*), and the Asiatic clam (*Corbicula fluminea*). Following the kill, no crayfish were present along transects, but recently collected census data are not significantly different from data collected before the 1991 kill (Paired *t*-test, $P > 0.1$). However, crayfish numbers have not returned to their pre-1991 levels in the cave passage where the highest crayfish density occurred before the kill. Also, the scarcity of small (<1.5 cm total length) crayfish suggests that the return to pre-1991 levels may reflect dispersal of animals from inaccessible portions of the cave and not replacement of crayfish through reproduction.

The troglobitic pallid cave crayfish, *Procambarus pallidus*, inhabits flooded caves in the Suwannee River drainage in north Florida (Franz and Lee 1982). These caves also are inhabited by other troglobitic and troglophillic species, including several species of catfish (Hale and Streever 1994), ostracods (Walton and Hobbs 1959), the American eel *Anguilla rostrata* (Franz et al. 1994), the Asiatic clam *Corbicula fluminea* (Streever 1992*a*), tubificidae worms (Streever 1992*b*), and the colonial cnidarian *Cordylophora lacustris* (Streever 1992*c*). Franz et al. (1994) provide an extensive review of Florida's cave fauna, emphasizing distributional records for all species reported in association with caves. Little is known about the ecology or population dynamics for most of these species.

The Peacock Springs cave system consists of over 3,300 m of fully-flooded passage, with depths down to about 60 m. Eight openings provide access to the cave system. A surface channel connects openings commonly called Peacock I, II, and III to the Suwannee River. Water from the Floridan aquifer normally flows out of the Peacock I opening and drains into the Peacock III opening and the Suwannee

River. However, during periods of high river levels, water from the Suwannee River overcomes the head of pressure generated by aquifer water. Flow in the surface channel reverses, and Suwannee River water enters the cave system. Following a flow reversal in February 1991, virtually all of the animals in accessible portions of the Peacock Springs cave system were killed. Animals affected by the kill include crayfish, catfish, and Asiatic clams (Streever 1992*b*). The cause of the kill is unknown.

This paper addresses two issues. First, I present 1994 *P. pallidus* census data and subjective observations of other taxa, and second I discuss a possible mechanism for the increase in crayfish population density following the 1991 kill.

METHODS

In 1990, divers established eight belt transects (100 x 4 m) in association with permanent guidelines in the Peacock Springs cave system. Transects were numbered 1–8. Both before and after the fauna kill in February 1991, crayfish were visually censused along transects by divers carrying 50-watt lights. Because cave crayfish roam in the open on the cave floor, visual censusing provides a simple method of estimating population density. After the kill, two additional belt transects, called 2-a (240 m long) and 8-a (350 m long), were established in a tunnel north of the Peacock I opening and north of the Peacock III opening, respectively. Transect 2-a incorporated transect 2, and transect 8-a incorporated transects 7 and 8. All crayfish that were visible from the cave's permanent guidelines were included in censuses along transects 2-a and 8-a, making their width dependent on water clarity and size of the cave passage. In general, the width of transects 2-a and 8-a varied between 4 and 10 m. The large size of the new transects was intended to allow censusing of the smaller crayfish densities occurring after the 1991 kill. A map of the cave showing transect locations was provided by Streever (1992*b*).

The 1994 transect censuses were made between 9 January 1994 and 25 November 1994. During the 1994 censuses, crayfish were recorded as belonging to a size class of less than or greater than 1.5 cm in overall length, estimated from the anterior edge of the rostrum to the posterior edge of the telson. All censuses along each of the original transects were averaged to yield values for each transect before the kill and in 1994. The null hypothesis of no difference between censuses taken before the 1991 kill and those taken in 1994 was tested by a paired *t*-test, with averages of before and after censuses along individual transects comprising pairs (Zar 1984).

RESULTS AND DISCUSSION

Differences in censuses (Table 1) before the 1991 kill and in 1994 are not statistically significant ($P > 0.1$). The increase in crayfish population density immediately after the kill and in 1994 suggests that the population is recovering. However, 1994 censuses in the Peacock III tunnel indicate that populations have not recovered to pre-kill levels along transects 7 and 8. Transect 8a, which encompassed transects 7 and 8 as well as an additional 100 m of cave passage, contained only a fraction of the number of crayfish that were present along transects 7 and 8 before the kill. This indicates that the large crayfish population found in the Peacock III tunnel before the kill is not recovering, nor is the overall population in the cave system.

Of the 138 crayfish censused after the 1991 kill, only one animal was smaller than 1.5 cm. Although animals smaller than 1.5 cm in total length may be missed during censusing, the scarcity of

Table 1. Census data for *Procambarus pallidus* in the Peacock Springs, Florida, cave system before the 1991 kill, immediately after the kill, and in 1994.

	Number of crayfish counted							
	Before 1991 kill			Immediately after 1991 kill		1994		
Transects	$\bar{x}$	S.D.	*n*	$\bar{x}$	*n*	$\bar{x}$	S.D.	*n*
1	1.0	1.0	3	0	1	1.0		1
2	6.5	0.5	2	0	1	1.0		2
2a[1]	not counted			0	1	9.7	5.4	3
3	1.5	0.5	2	0	1	7.0		1
4	4.0	0.0	3	0	1	0.0	0.0	2
5	1.0	0.0	4	0	1	1.0		1
6	6.2	0.8	5	0	1	6.0	1.0	2
7	34.5	2.7	8	0	1	0.0	0.0	8
8	49.5	7.1	8	0	1	0.0	0.0	8
8a[1]	not counted			0	1	10.1	6.6	8

[1] These transects were established after the 1991 kill to cover a larger area than original transects.

small animals suggests that recovery of crayfish population density is not dependent on replacement through reproduction. Cave populations frequently display size distributions with many large individuals and few small individuals, suggesting infrequent reproduction (Poulson 1963, Culver 1982). The fecundity of *P. pallidus* is unknown, but an extensive study of the cave-adapted crayfish *Orconectes australis australis* in Shelta Cave, Alabama, suggests that reproduction in cave crayfishes may be infrequent and that clutch sizes may be small (Cooper 1975). If a similar pattern occurs in *P. pallidus*, crayfish population recovery that depends on reproduction could be slow. Because crayfish population densities in the Peacock Springs cave system do not appear to be recovering through reproduction, the increase in numbers along transects 1 through 6 may not represent a true recovery of the crayfish population. Instead, crayfish density may be the result of colonization by individuals that survived the kill and are now moving into the portion of the cave where transects were located.

Catfish were not counted as part of this study. However, they were common along transects before the 1991 kill, they were absent from transects immediately after the kill, and they were common during the 1994 census dives. An Asiatic clam population near the mouth of Peacock III had an estimated density of 161 individuals/m^2 before the 1991 kill (Streever 1992*a*), but no live Asiatic clams were found immediately after the kill or in 1994. Empty clam shells, presumably remaining from before the kill, were abundant.

The causes of the kill and the factors affecting recovery are unknown. However, intrusion of river water into caves typically full of groundwater appears to be linked to cave kills in the Peacock system. On 19 November 1994, two dead crayfish and a dead catfish were found along transect 6, immediately after a period of flooding during which Suwannee River water entered the cave. However, seven live crayfish were found along the transect on the same day, so this event did not have the intensity of the 1991 kill. Despite this apparent association, the link between river water and crayfish mortality is not clear. *P. pallidus* has been observed in two siphon-spring cave systems flooded by Sante Fe River water throughout the year (personal observation), so intolerance of low temperatures and other environmental factors associated with river water may not be the cause of mortality. Furthermore, kills have been observed in other caves without flooding by river water (Franz et al. 1994). Establishment of the cause of cave crayfish kills requires further investigation.

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